Residual and Commercial Gas Discrimination by Spectral Decomposition Using Ultra-Far Stacked Seismic Data, Nile Delta, Egypt

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W. Fathy & A. Shams, Heriot Watt University

Introduction

One of the big challenges facing operators in the on-shore Nile Delta is the discrimination between residual gas saturations and mobile commercial gas. The application of spectral decomposition and frequency attributes on pre-stack seismic data has opened the door to think about the relationship between frequency attenuation and reservoir properties. The main motivation of this study is the existence of a potential accumulation, with a very good seismic response, extremely comparable to that observed in a major producing field nearby. The results of a well drilled in this prospect were not encouraging and the well was classified as a dry well with gas shows (gas saturation in the tested reservoir reached 28%). We will see in this study how spectral decomposition can be used to discriminate between low gas saturations and mobile, commercial gas in the area of study.

Methodology

The methodology started with making a proper analysis for SD-1 well, which was drilled 2 km south of the WD oil and gas-producing field. SD-1 well was dry well with gas shows.

A comprehensive revision was done for the pre-drilling scopes as well as the risk assessment and post drilling results. During drilling SD-1 well, the mudlog pointed out for gas shows in three levels of Qawasim reservoir (same reservoir for WD field), the gas reading reached to C4. The petrophysical analysis for the recorded log data confirmed the gas presence with average porosity 20% and gas saturation reaches 28%. Forward modelling using log data and the CDP gathers for both the drilled well and the producing field was conducted to assess the impact of changing reservoir properties on the seismic character at the two wells locations. Subsequent to building the rock physics model, AVO analysis was then applied on the ultra-far synthetic gathers to monitor the amplitude versus offset (angles) response in different cases (in-situ, gas case and wet case). Spectral Decomposition transforms the seismic data into the frequency domain via a Discrete Fourier Transform (DFT).

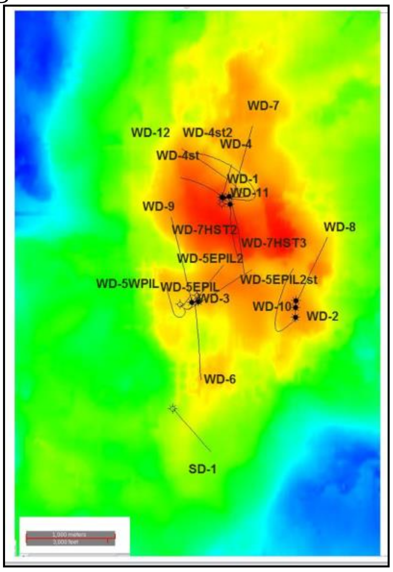

Figure 1: *Location map for WD field and SD-1 well*

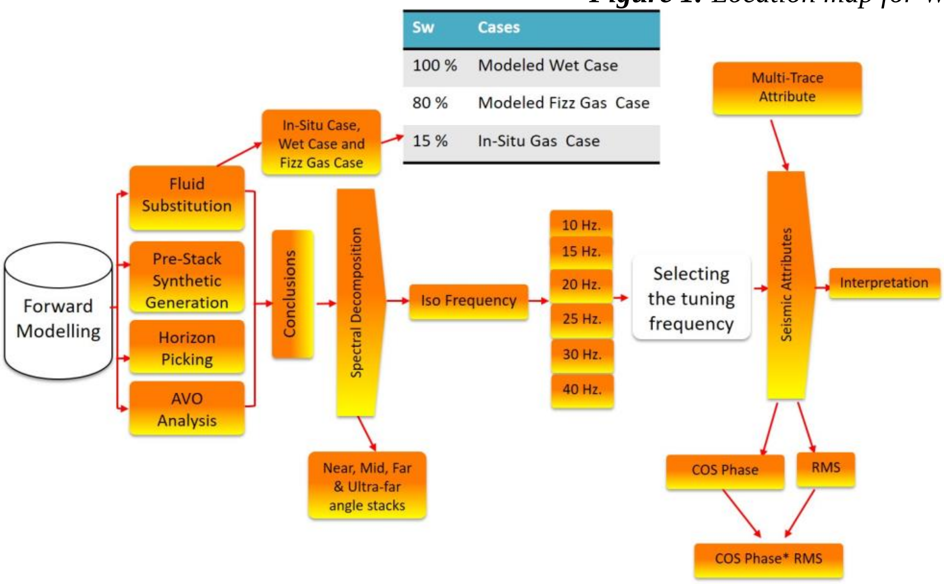

Figure 2: *Workflow for residual and commercial gas discrimination using spectral decomposition*

Gathers Conditioning

By looking into the quality of the pre-stack seismic data, we realized that there is a potential to improve the signal to noise ratio and proof the reliability of the ultra-far or high angles data, so, the gathers pre-conditioning becomes essential before proceeding in any reservoir delineation process (*Singelton, S. 2009*). We have iterated a several workflows with different parameters to apply the gathers pre-conditioning and preparing the data for further sophisticated process can aids in better understanding for the reservoir characteristics. The sub-angle stacks with different angle ranges (near, mid, far and ultra-far) had been generated using the angle gathers however, the ultra-far angle stack which shows both the best amplitude response and reservoir continuity. ***(Figure-3)***

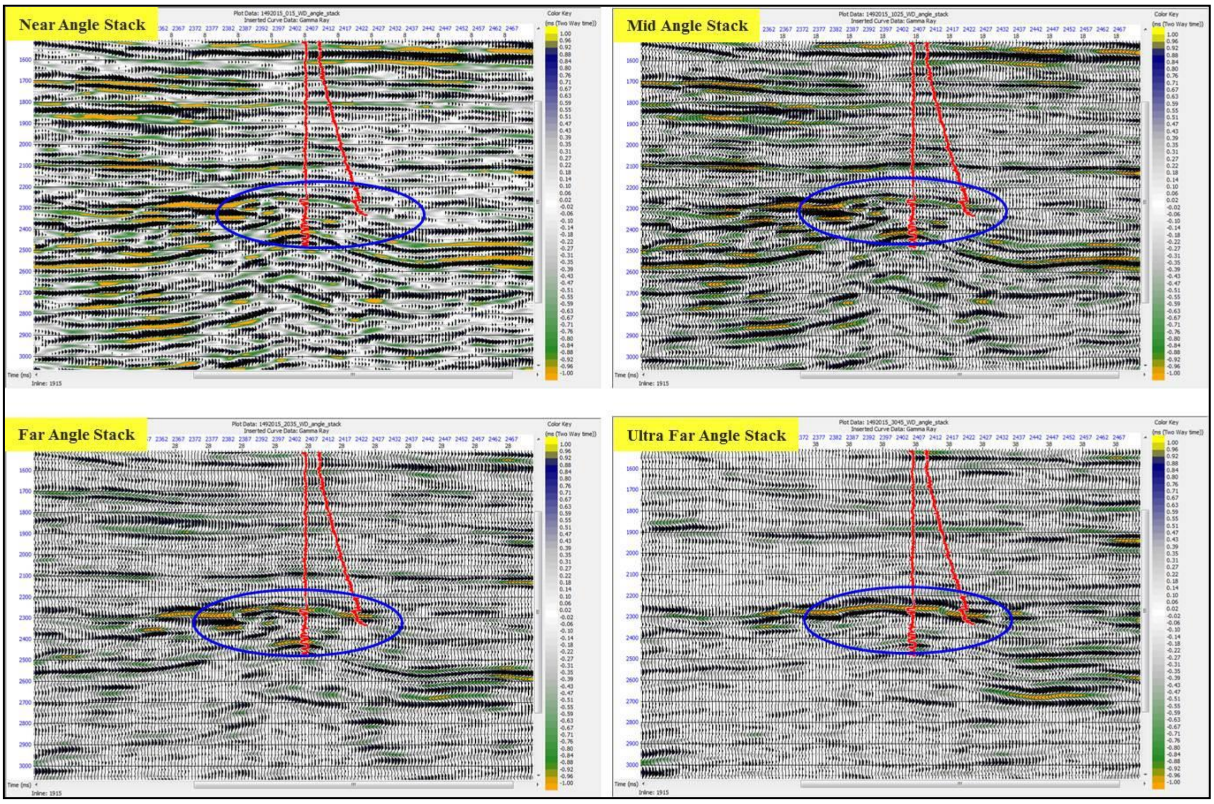

Figure 3: *Different angle sub-stacks resulted from the gathers conditioning*

Spectral Decomposition and Frequency Attributes

Spectral decomposition provides a tool for seismic interpretation. Spectral decomposition is used for imaging and mapping temporal bed thickness and geologic discontinuities over 3D surveys. This technology can improve the prospect definition beyond seismic tuning resolution and it can often help resolve what cannot be resolved in the time domain. The spectral decomposition is a technique that works in separating and classifying seismic events within each trace based on their frequency content. Spectral decomposition could be classified as hydrocarbon indicator. (Castagna 2003).

In physics, attenuation is the gradual loss in intensity of any kind of flux through a medium. The frequency-attenuation approach is used commonly on the commercial and low gas saturation discrimination by applying a spectral decomposition technique to the reservoir that shows hydrocarbon signature in the seismic data. Li and Han (2005). Different spectral attributes such as the attributes of peak frequency, bandwidth, and calculation of the Q factor show that the low saturation gas has higher attenuation than that of the commercial gas.

The spectral decomposition applied in two steps: a) Tuning Cube ***(Figure-4)***: applied on the ultra-far stacked data. The transformed results include tuning cubes and a variety of discrete common frequency cubes. The presented frequency slices resulted from the tuning cube process are (10 Hz, 15 Hz, 20 Hz, 24 Hz, 30 Hz, 35 Hz, 45 Hz and 55 Hz).

b) Volume Recon: During the Volume Recon process, a number of iso-frequency cubes are generated for a number of frequency ranges. After a number of iterations and using different parameters setting, we found that a TWT window of 1000-3500 is good enough to produce satisfactory results. The selected frequencies based on the results of the tuning cube are (10Hz, 15Hz, 20 Hz, 24 Hz, 30 Hz, 35 Hz, 45 Hz and 55Hz). The volume recon results can be viewed in horizon amplitude slices or sections for a selected time window of a desired frequency.

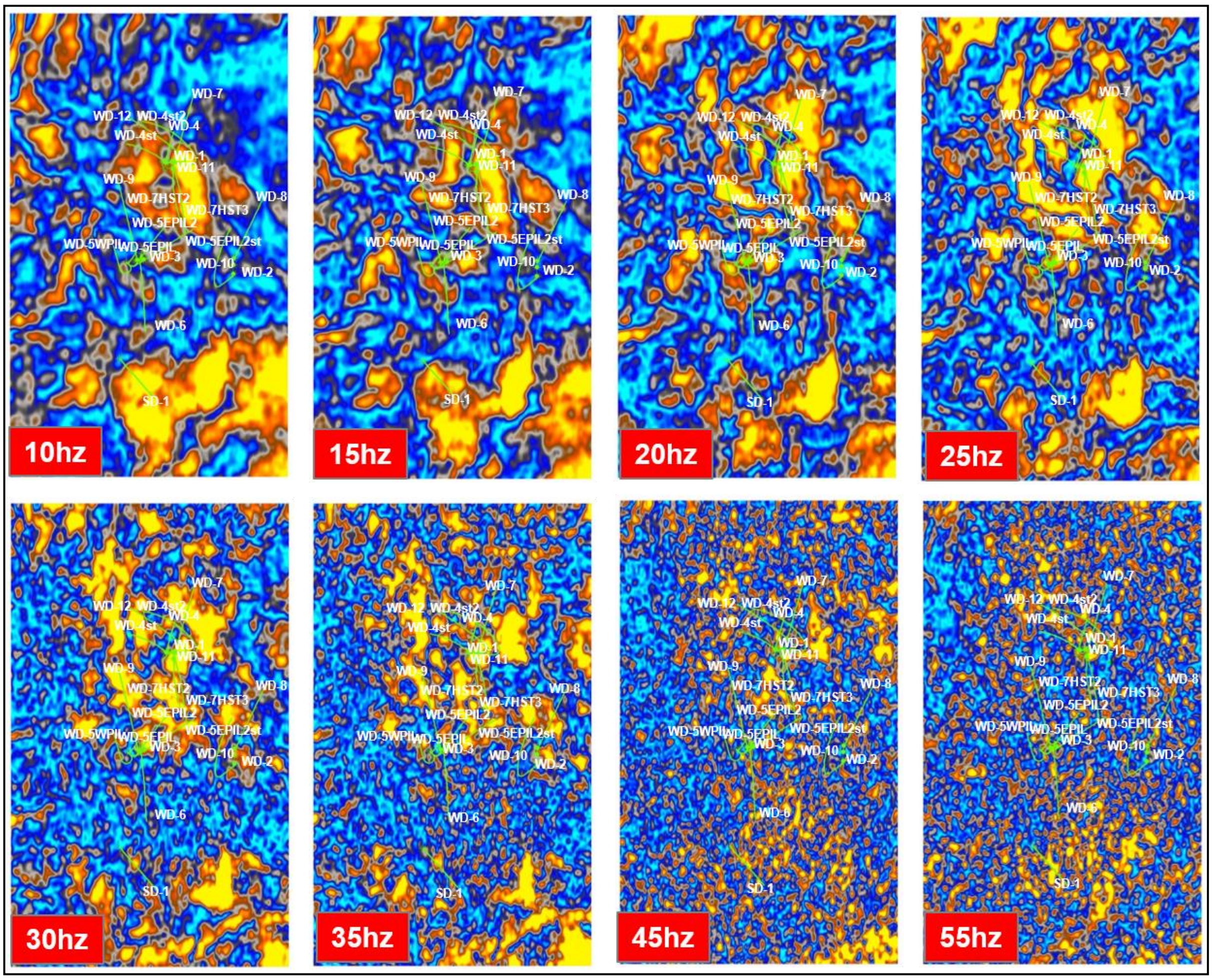

Figure 4: *we can notice that the lower frequencies (10HZ and 15Hz) shown higher amplitudes in both WD field and SD-1, however, the higher amplitude in WD field is following certain geometry (still it is not the final geometry of the field), ie. We can say it is the start of delineating the different sand lobes of WD field, which is fully hydrocarbon, saturated, on the other hand, In SD-1 just there is higher amplitude but without any geological features. In the frequency slices of 20Hz and 24Hz, the higher amplitude in SD-1 decreased intensely while in WD field it follows the geometry of the field (the different sand lobes can be easily recognized especially in the 24 Hz) in addition to the sustainability of the higher amplitudes. From 10 Hz to 24 Hz we can notice largely the cleanness of the data from noises.*

As a conclusive interpretation for the results of the spectral decomposition or in other words the main reason for getting higher attenuation in the low gas saturation and vice versa in commercial gas within the reservoir in the area of study. At higher water saturation, the large pores contribute significantly in the energy losses, while in lower water saturation the large pores are sufficiently drained for it is filled with a mixture of water and gas and no longer contribute to the losses. (William. F. Murphy, 1982.)

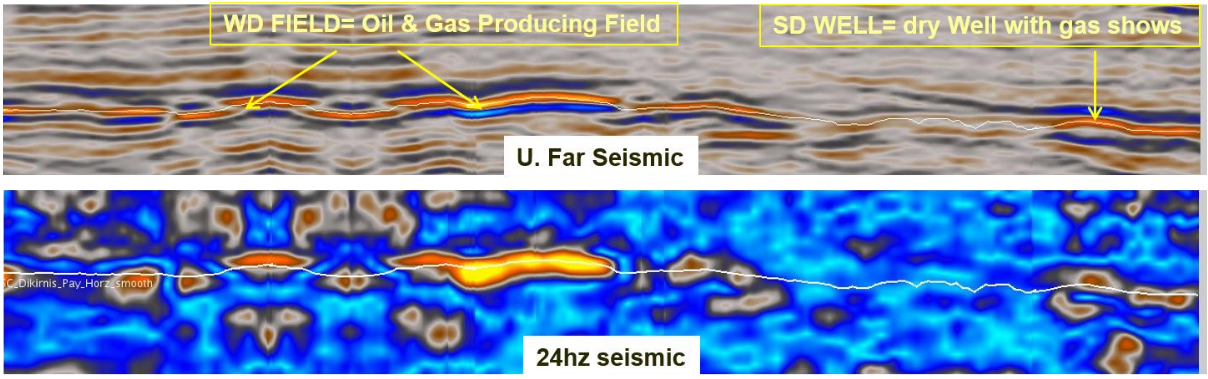

Figure 5: *arbitrary seismic line through WD field in the north and passing through SD-1 well in the south from the ultra-far stacked seismic data (The upper section); we can notice very strong amplitude in both locations with the same strength and the seismic character, but WD field is located in a high structural position. (The lower section) is an arbitrary line from the 24 Hz iso-frequency cube. This line shows completely different response rather than the ultra-far seismic in which, the amplitude at WD field is very bright indicates lower attenuation and confirmed the commercial gas within the reservoir, while in SD-1 well there is very faint amplitude which confirmed the low gas saturation found after drilling this well. The frequency attribute confirmed the false anomaly appears in the conventional seismic, which again highlight the importance of spectral decomposition or frequency attributes in prospects evaluation and its role in the low gas saturation and commercial gas discrimination.*

Conclusions

The application of spectral decomposition, frequency attributes and amplitude attributes on the ultra-far stacked data shows excellent results in terms of the tuning frequency response at each of the producing field and the drilled well. The strong relationship between gas saturation and frequency attenuation was proven and will be shown in this study. As mentioned by Castagna in 2003 that 'The spectral decomposition could be classified as hydrocarbon indicator". The work done in this study will broaden the role of spectral decomposition and frequency attribute analysis beyond its use as a hydrocarbon indicator by further emphasizing its role in reservoir properties delineation.

Acknowledgement

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